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SOGRA – Supporting Optimized GNSS Research in Africa

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14. ABSTRACT

This effort was a collaborative project between AFRL (Air Force Research Laboratory) and UBI (University of Beira Interior) supported by EOARD (European Office of Aerospace Research & Development). The major initial investment concerning the research done under SOGRA was focused on the development of an integrated system capable of being installed at remote locations. A prototype was developed and installed at some locations in Africa. The next development (the upgrade of the network) started in 2010 with several missions to survey the feasibility of new stations and the installation of the new station at Zanzibar, Tanzania in July 2010. The final portion of the effort was the daily processing of the observational files for the SCINDA network using the GIPSY-OASIS software package. Scintillation events can cause sudden changes in coordinate positions (or even prevent their calculation). They can be misinterpreted as real displacements due to earthquake events. Algorithms were developed to take into account the influence of scintillation events during the processing of the GPS data. The objective was to verify the level of the correlation between scintillation events in the region and abnormal positioning solutions. The positioning solutions were compared in single mode (using the GIPSY-OASIS software package with the Precise Point Positioning strategy) and in differential mode (using TBC, a commercial software). The results were compared to those obtained using dedicated software (RINEX_HO) developed to correct the GPS observables for second- and third-order ionosphere effects. The conclusions are that the improvement is marginal for most positioning applications, namely for surveying, but can slightly improve the accuracy of the derived time-series.

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REPORT

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SOGRA

Supporting Optimized GNSS Research in Africa

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EOARD (European Office of Aerospace Research & Development)

AFRL (Air Force Research Laboratory)

1 Introduction

This report describes the activities carried out in the framework of the SOGRA (Supporting Optimized GNSS Research in Africa) project, which was a collaborative project between AFRL (Air Force Research Laboratory) and UBI (University of Beira Interior) supported by EOARD (European Office of Aerospace Research & Development). The initial period was between August 2009 and July 2011 – However, due to the successful results of the first period, the SOGRA project was renewed for three more years finalizing in July 2014. The mains goals (as described in the submitted proposals) were the following:

a) System Design – Definition of necessary features in order that the designed system (GPS receiver, support computer and other auxiliary equipment) will serve a multitude of scientific and technical applications simultaneously. The focus will in the installation, maintenance and development of the necessary software. Since AFRL already developed its scintillation software using the Linux platform, this OS will be used as the basis for further development.

b) Network Development – After development of the GPS system, the existing network managed by the two groups will be gradually updated. Many of the locations installed by UBI-IDL are running Windows machines as auxiliary computers to data storage and transfer. The conversion to Linux machines will be done and new software applications implemented. If necessary, new monuments will be constructed in order to upgrade the stations to the desired standards. Additionally, the (common) network will be densified with the installation of some more stations at particular spots in Africa. Therefore, we request that the total time of the project will be extended for two years.

c) Influence of scintillation events in positioning – Scintillation events can cause sudden changes in coordinate positions (or even prevent their calculation). They can be misinterpreted as real displacements due to earthquake events. Algorithms will be developed in order to take into account the influence of scintillation events during the processing of the GPS data. This processing will be done locally in order to avoid the continuously streaming of large amount of data. In this aspect, the use of Precise Point Positioning (PPP) strategies will be investigated together with the use of temporal filtering.

2 Execution

2.1 Work Package 1 – System Design

The major initial investment concerning the research done by the fellowship researchers contracted by SOGRA was focused on the development of an integrated system capable to be installed at remote locations. Figure 1 shows details of the prototype developed that have been installed in the following years at some locations in Africa.

Figure 1 – Prototype developed for the integrated system. (left) cabinet hosting the equipment; (right) antenna monument and solar panels. Example of a system installed in Angola.

During the development, several aspects of the different components were analyzed and developed, in particular:

a) Receiver - the system has been developed in order to be independent of the receiver used (currently, the system is working with different models from three different vendors).

b) Router - this equipment manages all local processing and the communications using mobile communications (UTMS or EDGE). The collaboration with AFRL (ionospheric research) intends to develop systems that can be used by different applications: ionospheric research implies data acquisition at high frequencies (>20Hz) that it is impossible to transfer using available communications at many worldwide locations. Therefore, local processing is required. Consequently, in the last years, new devices were tested, in particular it was decided to develop the system using a different router with two usb ports (cf Figure 2). The idea is to have simultaneously mobile communications (using a usb modem) and local storage (up to several GBytes).

Figure 2 – System installed at one of the SEGAL stations (Rodrigues, Mauritius), which data are now accessible to SCINDA since the installation of the router (in the center).

SEGAL developed tools that permit to establish 2-ways communications with the remote systems using mobile communications. In particular, SEGAL implemented using SSH tunnels in order to access the remote systems. In countries like Nigeria, mobile communications are using NAT protocols, which prohibits any external access since no unique IP is attributed to the system. Therefore, it is the router that needs to initiate any communication by establishing a permanent VPN tunnel.

c) In the last years, an alternative system to store data and handle the communications using Rasperry Pi mini-computers (cf. Figure 3) was tested. Although such computers have limited computational capacities, they are a very cheap and replaceable alternative to control the entire system.

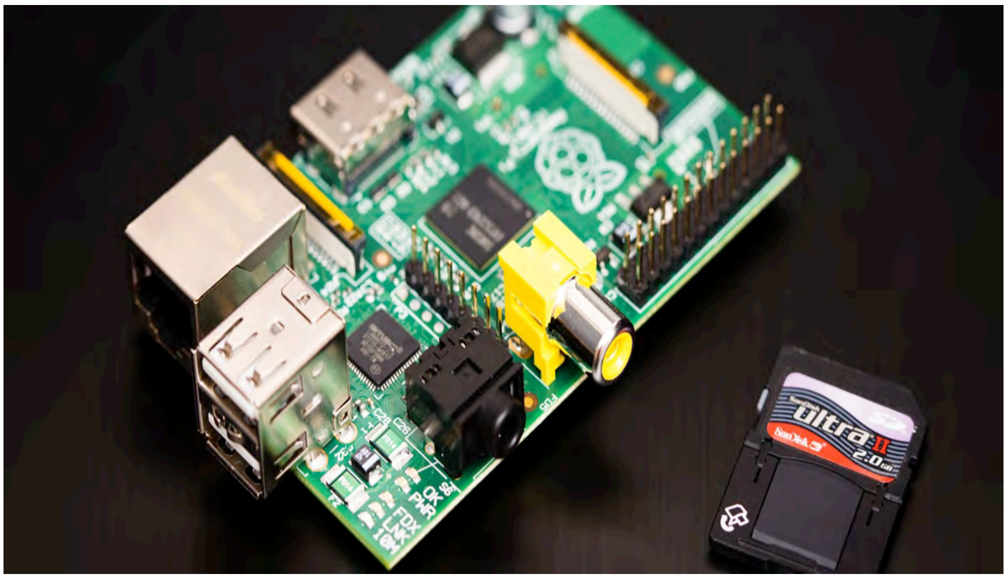

Figure 3 – Rasperry Pi micro-computer without cover.

d) Power management - there is redundant power supply. The receiver and router work both on solar panel and on electrical grid (when available). The radios (used to stream RTK corrections, if necessary for the local partners) only work on the electrical grid.

2.2 Work Package 2 – Network Development

The development of the network started on 2010 with several missions to survey the feasibility of new stations and the installation of a new station at Zanzibar, Tanzania in July 2010.

The surveys missions were carried out in West Africa (Nigeria and Sierra Leone) and Tanzania. In addition, one mission was carried out to Washington in order to attend the AfricaArray meeting. AfricaArray is a project focused on the geodynamics of Africa. The installation of GPS systems is a major component of this project and therefore it was considered important to discuss with them possible future common installations.

Figure 4 shows the first installed site, done in Zanzibar, called ZNZB, which was installed in collaboration with the local Survey Department of Zanzibar and the Survey Department of Tanzania. The installation of this station in compliance with geodetic standards was also an important development of the SOGRA project since it makes the station not only available for Ionospheric research but also for other technical (e.g., support to surveys) and scientific (e.g., geodynamic studies) applications.

Figure 4 and Figure 5 show also details of the monuments, a self-center mounting device, which permits the replacement of the antenna with millimeter-level accuracy if necessary.

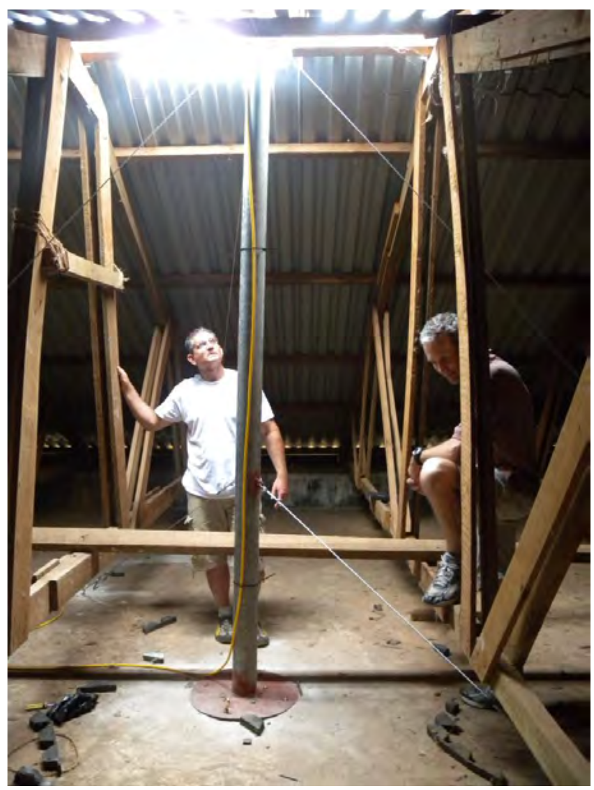

Figure 4 – Site ZNZB. (upper left) antenna on the self-center mounting device installed on the top of a mast; (right) mast inside of the roof solidly linked to the structure (wires used to tension the mast); (lower left) installation team with the antenna on the background.

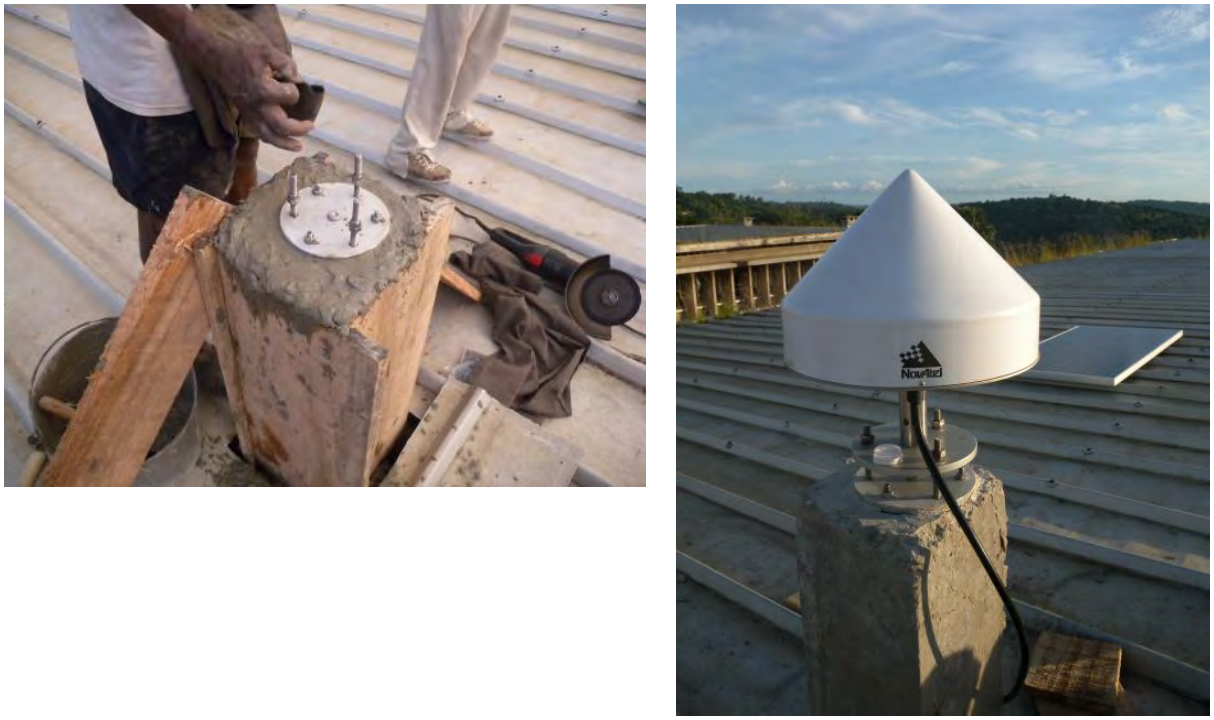

Figure 5 – Site FKIS (Kinshasa). Details of the antenna monument and ancillary equipment.

SEGAL also developed a web page in order to allow to permanently monitoring the status of the data transfer for the SCINDA stations. Figure 6 shows the main page (ordered by date of arrival time of latest received observational file) of the MGN-SCINDA site (located at http://segal.ubi.pt/GNSS/SCINDA). SEGAL still maintains this web page, which features have been developed during the execution of the project (e.g., to automatically send warnings to the SCINDA group and local partners when the regular transfer of the data does not succeed).

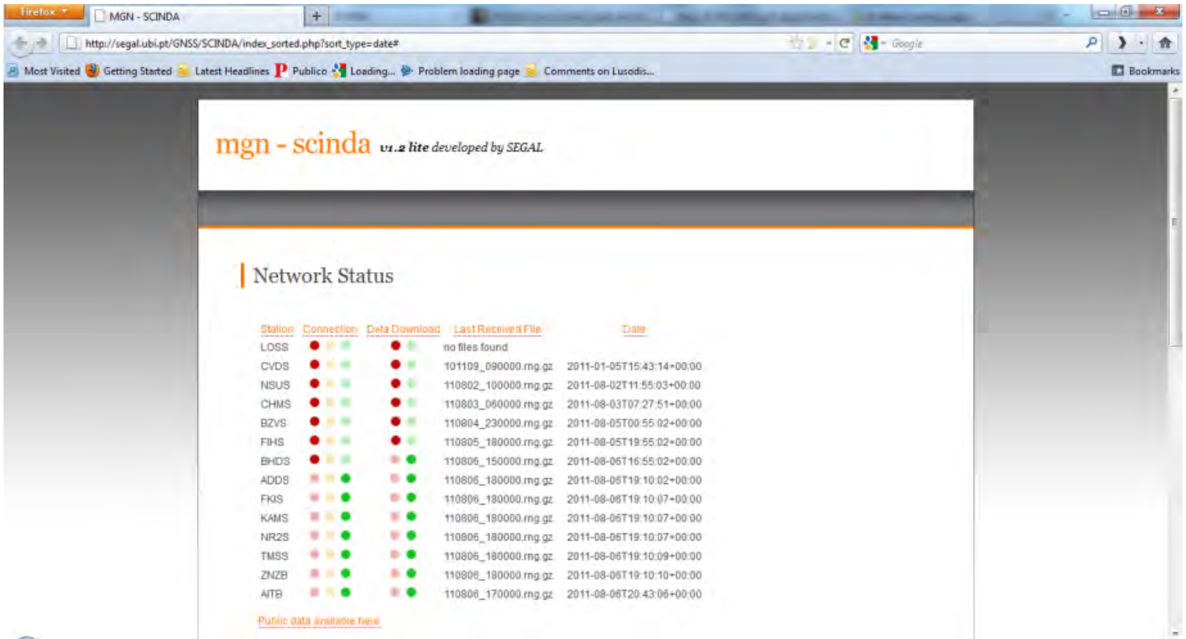

Figure 6 – MGN (Monitor of GNSS Networks) web page.

2.3 Work Package 3 – Influence of scintillation events in positioning

SEGAL processed on a daily basis the observational files for the SCINDA network using the GIPSY-OASIS software package. The computation of the daily solutions with respect to the latest realization of the International Terrestrial Reference System, ITRF2008, permits to identify any unexpected variation on the estimated positions.

Figure 7 exemplifies the computed time-series for one of the SCINDA stations, ZNZB (Zanzibar). The left figure shows the initial studies using data until 2013 whereas the right figure shows the latest results produced in the framework of the SOGRA project where already is possible to observe the existence of seasonal signals in the time-series.

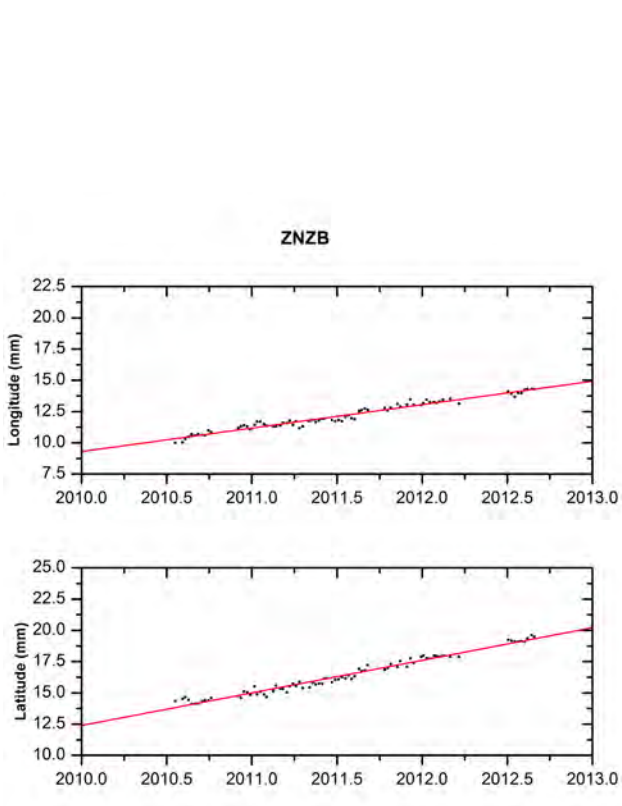

Figure 7 – Time-series for ZNZB (Zanzibar) site. Left: computed until end of 2012); Right: computed until February 2014.

This station (like other SCINDA stations) has been used to also compute the angular velocities of the tectonic blocks in Africa, namely around the East African Rift. Figure 3 shows the recent results obtained for the relative motions of Africa using also the SCINDA stations.

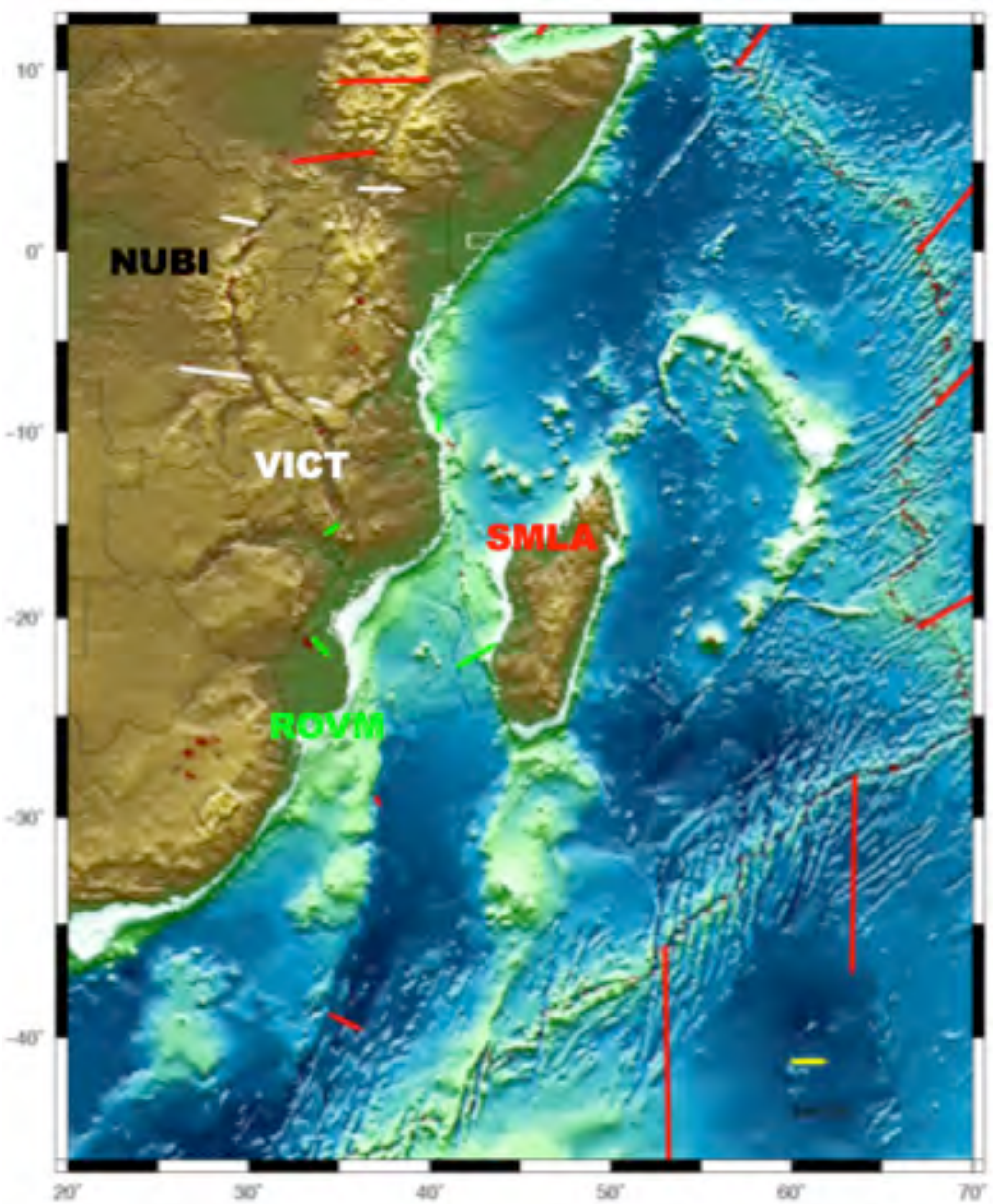

Figure 3 – Relative motions in the East African Rift region. Different blocks are held fixed in order to show the relative motion with respect to the neighboring tectonic blocks: (red) NUBI wrt SMLA; (white) NUBI and SMLA wrt VICT; (green) NUBI, SMLA, and VICT wrt RVMA.

The relative motions between the different blocks are small, in the order of few mm/yr for most of the plate boundaries. The major values are obtained in the Afar region (~6mm/yr) whereas the relative motions of the RVMA plate are very small and not statistically significant.

Additionally, the level of the correlation between scintillation events and abnormal positioning solutions has been investigated in the last year. Sub-daily solutions were computed for some scintillation events. The data were processed using the kinematic mode with the GIPSY-OASIS software package. GIPSY-OASIS is considered a academic software with unique characteristics, namely the capability to compute the positions of each station individually in a strategy known as PPP (Precise Point Positioning). The results obtained showed that the Kalman filter used by GIPSY mitigates most of the effects. Therefore, although the scintillation events can increase the associated uncertainties, the positions are not largely affected. In any case, we consider that more study cases would be necessary to be performed, namely using other processing software packages and real-time data

Sanit Arunpold, a PhD student from AIT (Asian Institute of Technology), Thailand, was at SEGAL from March to July 2012 investigating the location accuracy due to Ionosphere Scintillation. The objective was to verify the level of the correlation between scintillation events in the region and abnormal positioning solutions. He used data from the Singapore's SiReNT network, which is currently formed by seven stations distributed over an area of approximately 50Km by 25Km. He compared the positioning solutions in single mode (using the GIPSY-OASIS software package with the Precise Point Positioning strategy) and in differential mode (using TBC, a commercial software). He also compared the results obtained using dedicated software (RINEX_HO) developed to correct the GPS observables for second- and third-order ionosphere effects. The conclusions are that the improvement is marginal for most positioning applications, namely for surveying, but that can slightly improve the accuracy of the derived time-series.

3 Financial Execution

The dotation of the SOGRA project was divided in 4 tranches as shown in Table 1. The exact received value depended of the fluctuations on the exchange rate between US Dollars and Euros. The last tranche was only received in March 2014. However, the Administration of the University of Beira Interior supported the activities during 2013 and part of 2014.

Table 1 – Funds Received

Tranche	Value (USD)	Value (EUR)
1	36 000.00	26 100.98
2	25 000.00	18 320.92
3	33 000.00	25 012.42
4	57 000.00	41 027.32
Total	151 000.00	110 461.64

The following tables show the financial execution of the project per year.

Table 2 – Year 01: August 2009 – July 2010

Item	Value (EUR)
Human Resources	5,298.23
Acquisition of Services	0.00
Missions	6,710.15
Other Expenses	0.00
Equipment	378.58
Total	12,386.96

Table 3 – Year 02: August 2010 – July 2011

Item	Value (EUR)
Human Resources	18.458.23
Acquisition of Services	0.00
Missions	14.531.68
Other Expenses	1.608.04
Equipment	696.33
Total	35,294.27

Table 4 – Year 03: August 2011 – July 2012

Item	Value (EUR)
Human Resources	12 575.08
Acquisition of Services	0.00
Missions	11 496.56
Other Expenses	0.00
Equipment	696.33
Total	24,768.97

Table 5 – Year 04: August 2012 – July 2013

Item	Value (EUR)
Human Resources	16 525.36
Acquisition of Services	0.00
Missions	6 904.67
Other Expenses	1 063.63
Equipment	374.97
Total	24,868.63

Table 6 – Year 05: August 2013 – July 2014

Item	Value (EUR)
Human Resources	6540.33
Acquisition of Services	0.00
Missions	6123.32
Other Expenses	0.00
Equipment	482.15
Total	13,145.80

Table 7 summarizes the costs per year.

Table 7 – Year 01: August 2012 – July 2013

Years	Value (EUR)
Year 01: August 2009 – July 2010	12,386.96
Year 02: August 2010 – July 2011	35,294.27
Year 03: August 2011 – July 2012	24,768.97
Year 04: August 2012 – July 2013	24 868.63
Year 05: August 2013 – July 2014	13,145.80
Total	110,461.64

4 Output

During the execution of the project, several papers and presentations were prepared and presented at several meetings:

Fernandes, R.M.S. (2010), "Optimizing the use of GNSS stations: Applications on Tectonics and Meteorology", East, Central and Southern Africa GNSS and Space Weather Workshop, July 2010, Nairobi, Kenya.

Fernandes, R.M.S. (2012), "GPS for Geosciences at SEGAL: from second to secular", 3rd ACAG, Helwan, Egypt.

Fernandes, R.M.S., M.S. Bos, J. Apolinário, M. Meghraoui (2014), "Mapping the tectonic motions of the African continent with cGNSS", Wegener 2014, 1-4 September, Leeds, United Kingdom.

Fernandes, R.M.S., J. Apolinário, H. Valentim, P. Venâncio, N. Gonçalves (2013), "Optimizing GNSS CORS networks at remote locations", FIG Working Week, July, Abuja, Nigeria.

Fernandes, R.M.S., J.M. Miranda, D. Delvaux, D.S. Stamps, E. Saria, Re-evaluation of the kinematics of Victoria Block using continuous GNSS data, Geophysical Journal International, doi: 10.1093/gji/ggs071, 2013.